New Developments in Operator Protection for Forest Machines

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Forest Mechanization

- Forest harvesting has become safer with increased mechanization

- Mechanization sometimes creates new hazards

Safety Standards

- ISO 11850 provides safety requirements for forest machines

FINAL
DRAFT

INTERNATIONAL
STANDARD

**ISO/FDIS
11850**

ISO/TC **23**/SC **15**

Secretariat: **SFS**

Voting begins on:
2002-10-24

Voting terminates on:
2002-12-24

Machinery for forestry — Self-propelled machinery — Safety requirements

Matériel forestier — Machines automotrices — Prescriptions de sécurité

Safety Standards Issues: *New Hazards*

- ISO 11850
  - 4.2.2.3 Operator Protective Structures

    "The operator shall be protected from the hazards caused by failed chains, teeth and similar failures using polycarbonate or equivalent glazing, or other appropriate guards or shields, or both.

    NOTE: Criteria are to be developed

- ISO 8082 Rollover Protective Structures (ROPS):

  "Research is currently underway to develop a test method and criteria for machines having a rotating platform with cab and boom."

Information Needed for New Standards Development

- Groups are currently working on
  - new ROPS guidelines for excavator-based machines
  - New Thrown Object Protection guidelines for machine cabs
- Information is needed to characterize dynamic loads and energy exposure during rollover and thrown object impacts
- *Goal of research at Auburn:*
  - Characterize relationships between machine size and configuration and dynamic loads applied to the ROPS during rollover events
  - Develop cab design guidelines and procedures for testing cabs against thrown objects

ROPS Requirements

- Forest machines that have rotating upper structures with cab and boom mounted on the platform are excluded from the requirement for Roll Over Protective Structure

ROPS Requirements

- Traditional assumptions for hydraulic excavator-based machines
  - less susceptible to rollover – mainly worked on flat terrain
  - boom provided protection for cab during rollover

Is a forestry excavator different?

Conventional Excavator

Forestry Conversion Excavator

ROPS Needs

- Excavator-based forest machines now work in steep terrain

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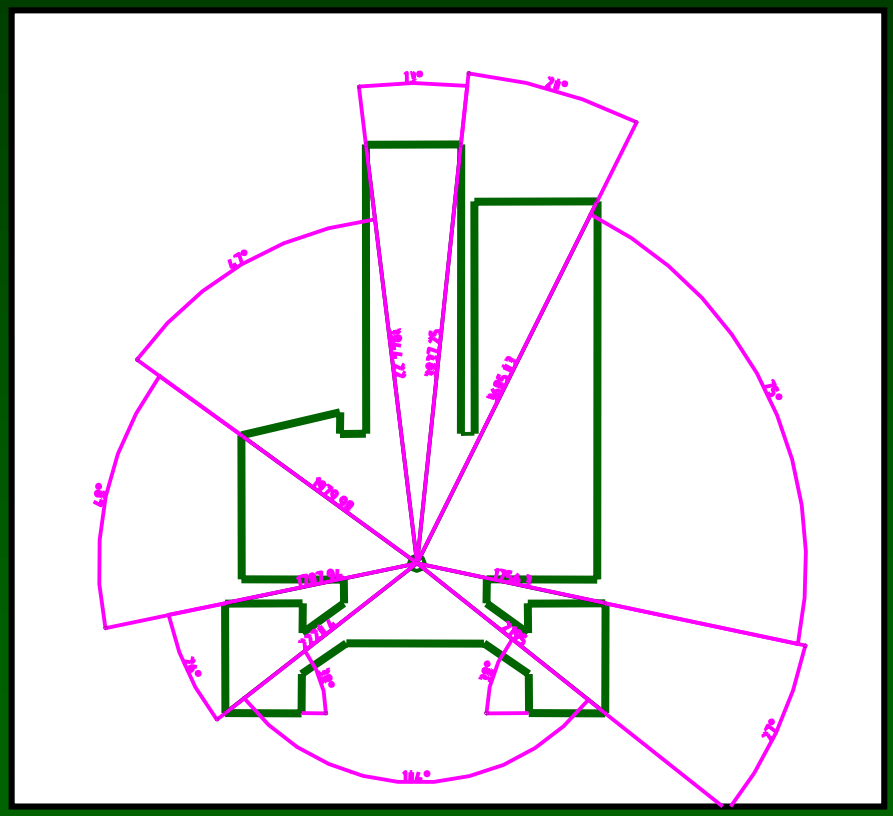
Rigid Body Analysis

- Analytical means of estimating levels of energy to which the cab will be exposed during an excavator rollover.
- Conservative approach
- Key assumptions:
  - The vehicle contacts a non-deformable surface
  - The vehicle impacts occur at successive contact points and each impact is treated as a separate event
  - Momentum => Angular Velocity => Kinetic Energy
  - Kinetic energy equals the total work done when trajectory of machine changes

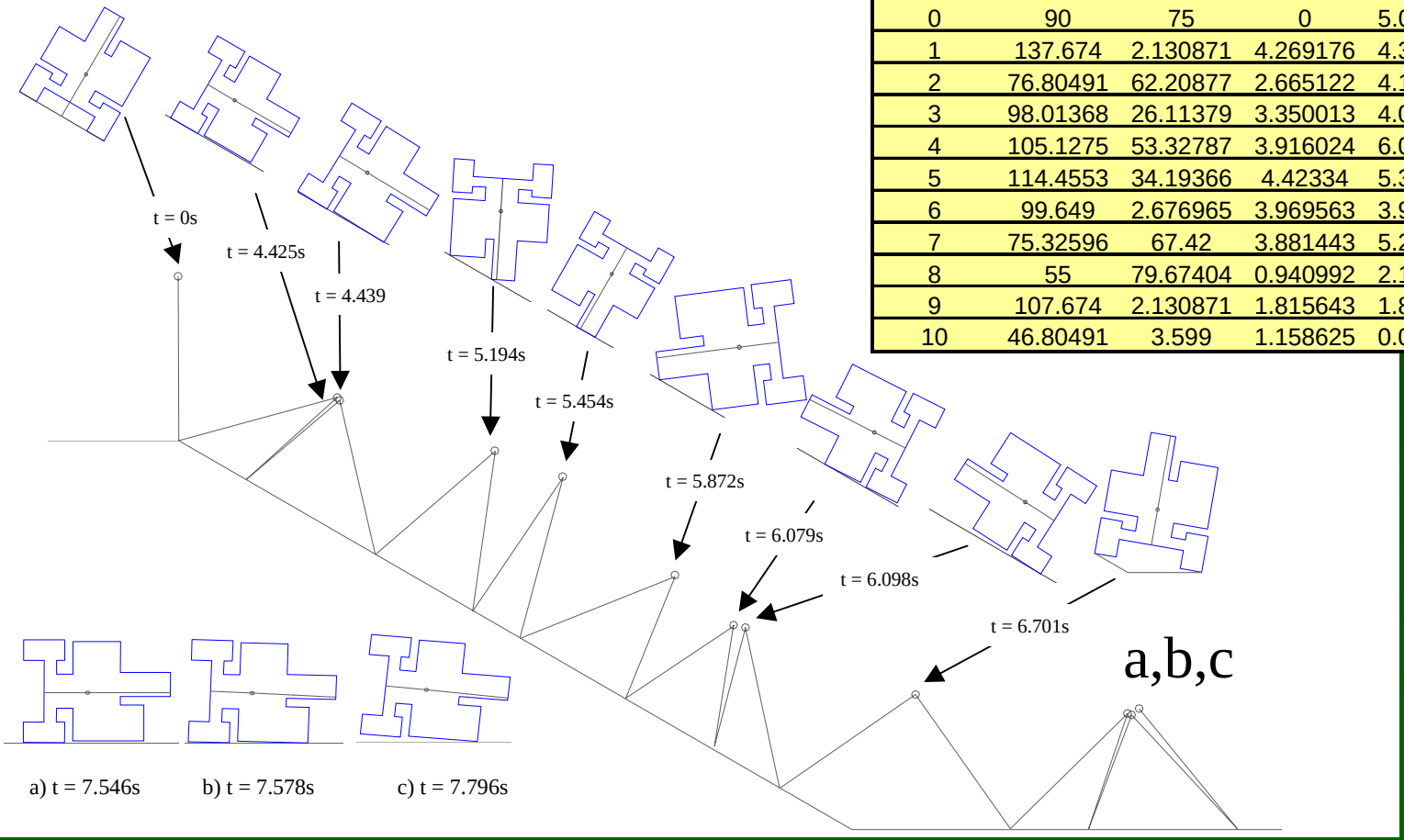
Rigid Body Analysis

- Machines Analyzed
  - Crawlers
  - Hydraulic Excavators
  - Hydraulic Excavators modified for Forestry
    - 46-cm cab riser
    - 122-cm cab riser
- Dimensions gathered from manufacturer spec sheets and field measurements

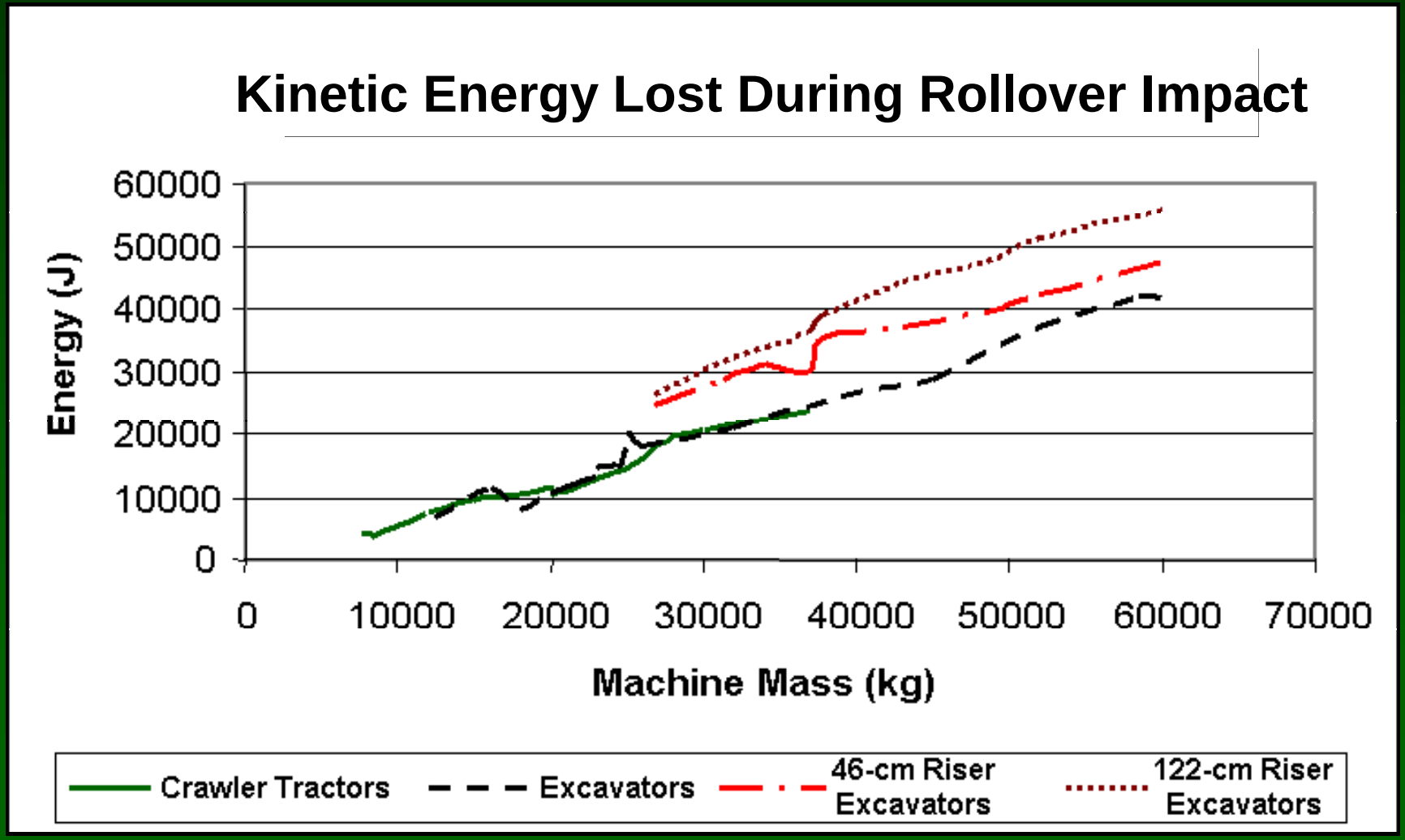


20 ton Hydraulic Excavator data

Solution Matrix						
r	phi	phi*	V	V*	dt	t
0	90	75	0	5.021677	4.42523	4.42523
1	137.674	2.130871	4.269176	4.341304	0.013632	4.438862
2	76.80491	62.20877	2.665122	4.167868	0.755542	5.194404
3	98.01368	26.11379	3.350013	4.076103	0.25955	5.453954
4	105.1275	53.32787	3.916024	6.004826	0.417846	5.8718
5	114.4553	34.19366	4.42334	5.399857	0.207366	6.079165
6	99.649	2.676965	3.969563	3.994401	0.018936	6.098101
7	75.32596	67.42	3.881443	5.232882	0.602576	6.700677
8	55	79.67404	0.940992	2.135675	0.84572	7.546397
9	107.674	2.130871	1.815643	1.887322	0.03156	7.577957
10	46.80491	3.599	1.158625	0.015452	0.217906	7.795862



Analytical Results

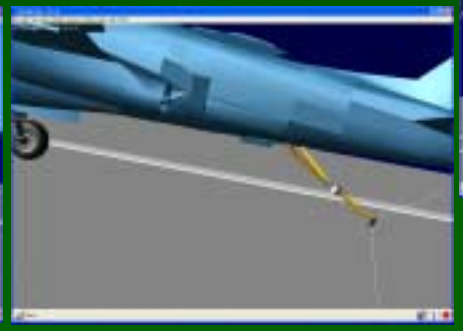


Limitations of Rigid Body Analysis

- Rigid body is a simplified 2-D analysis
  - Rollover events occur in 3-D space – many different possible contact points for which 2-D analysis cannot account
  - Rigid body cannot account for energy absorption in machine structure and soil surface

Simulation Modeling

- Multiphysics simulation models have been used to study performance of automobiles, aircraft, construction equipment, etc.



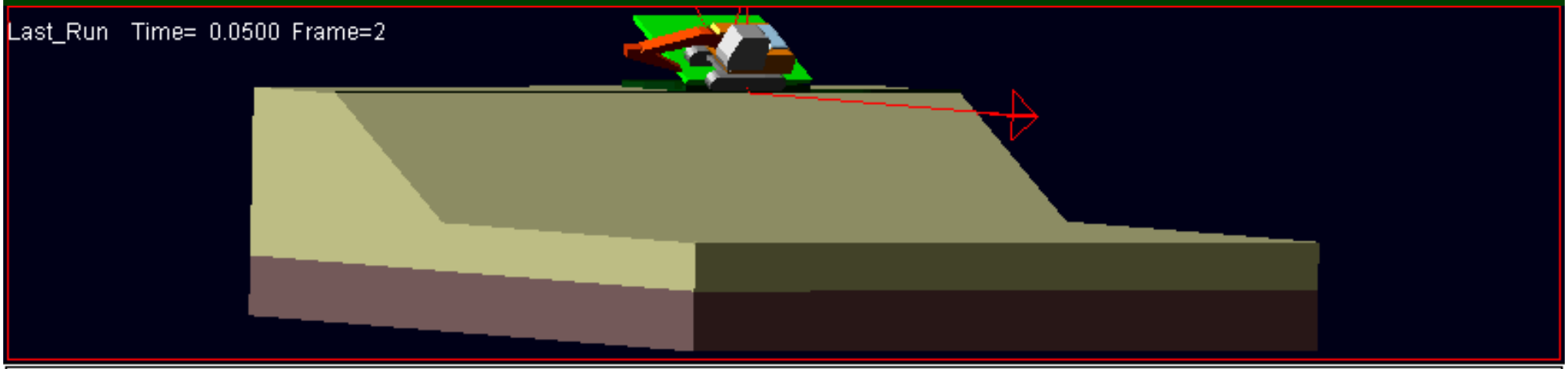
Simulation Modeling of Rollover

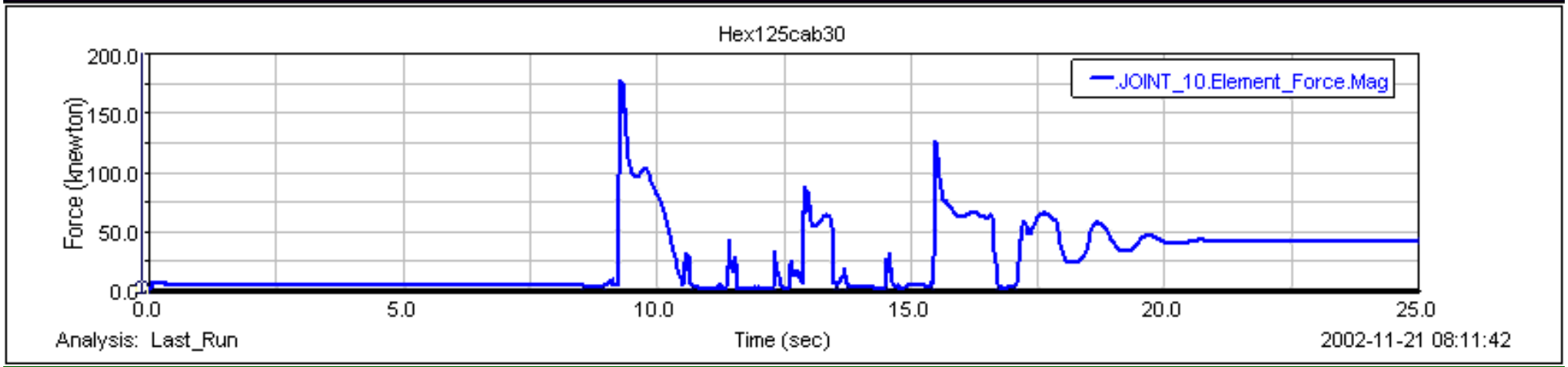
- Modeling forest machine performance is a new application of multiphysics simulation.
- MSC.ADAMS was used to develop simulation models of rollover of excavators and crawler tractors

- Manufacturers' literature and field measurements used to develop three-dimensional models of the excavators
- Soil surface modeled as a series of non-linear spring dampers

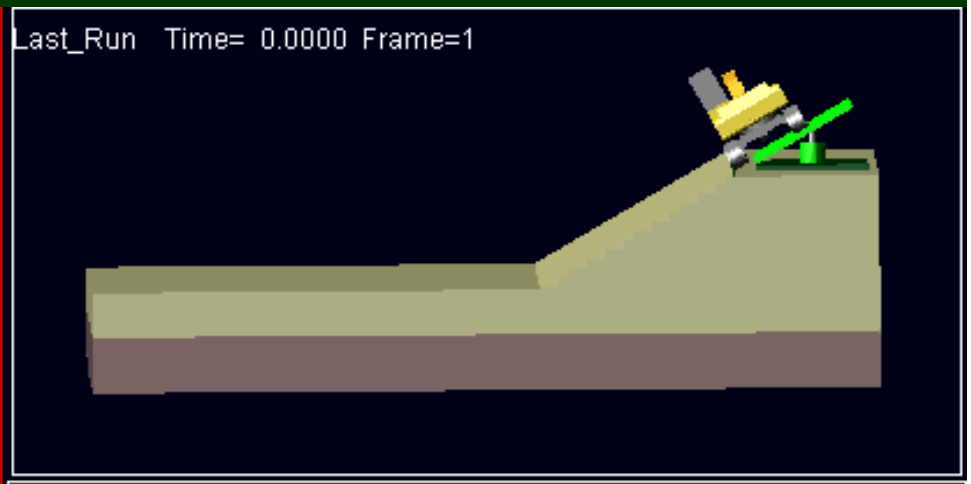
Simulation Results

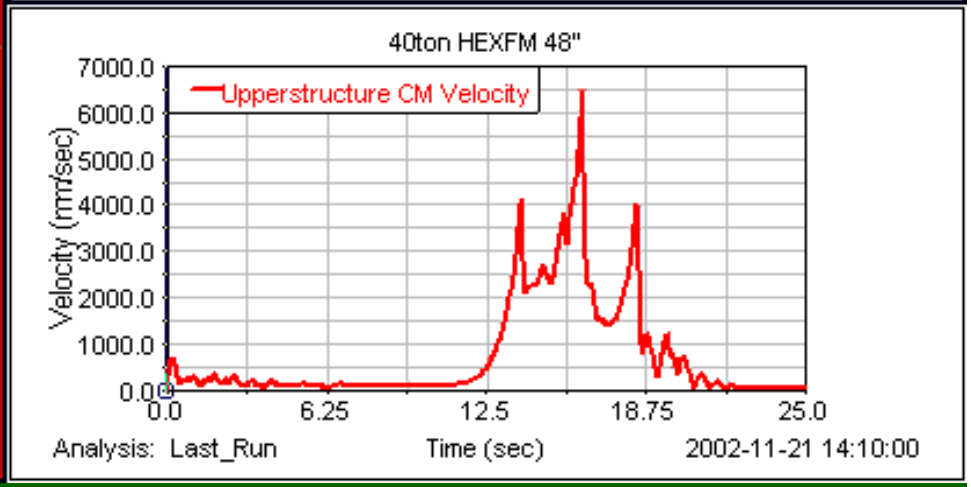
- Hydraulic excavator-based machine with 46-cm-tall cab riser



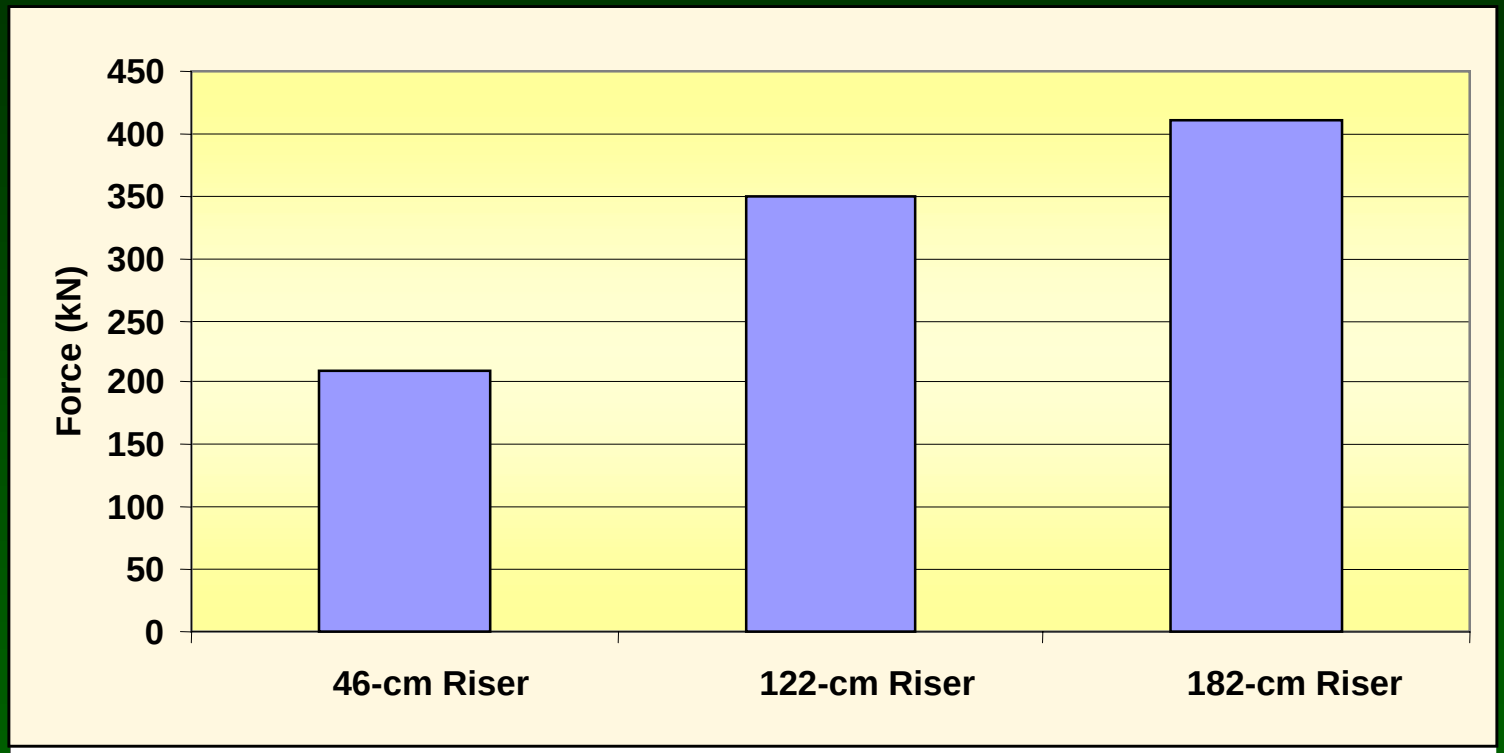


- Hydraulic excavator-based machine with 122-cm-tall cab riser

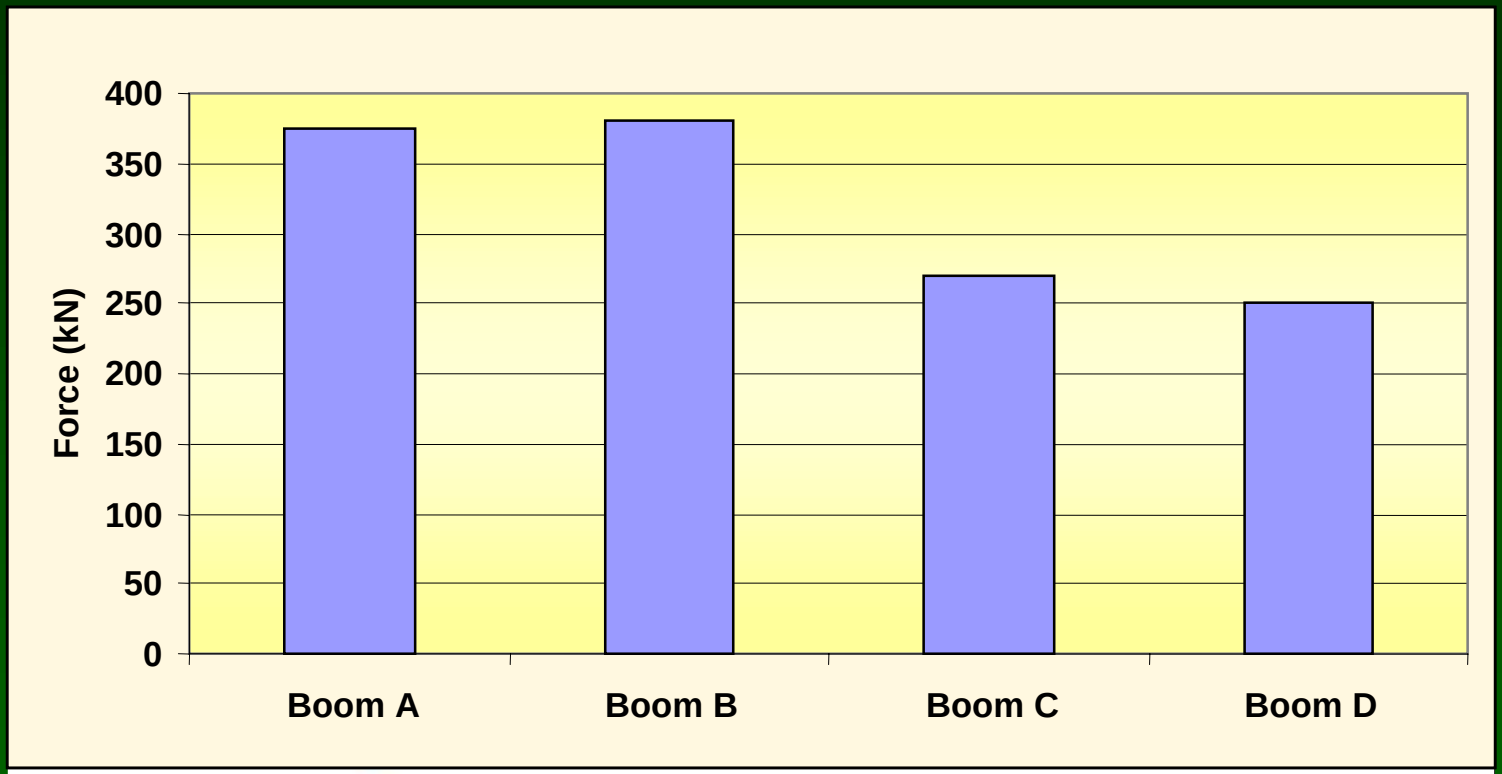




Effect of cab riser height on lateral forces on the cab during rollover



Effect of boom position on maximum forces on the cab during rollover



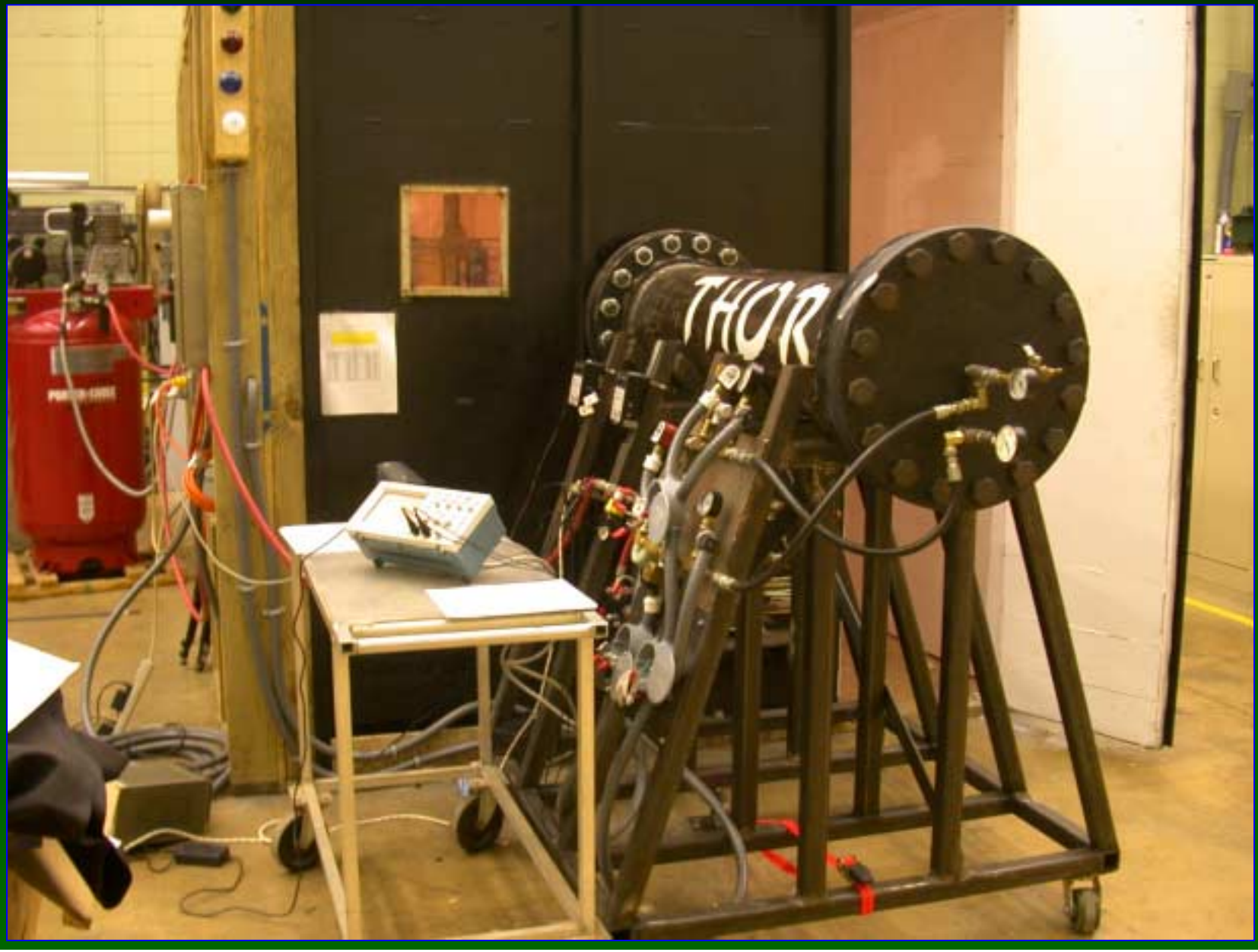
Summary for ROPS Research

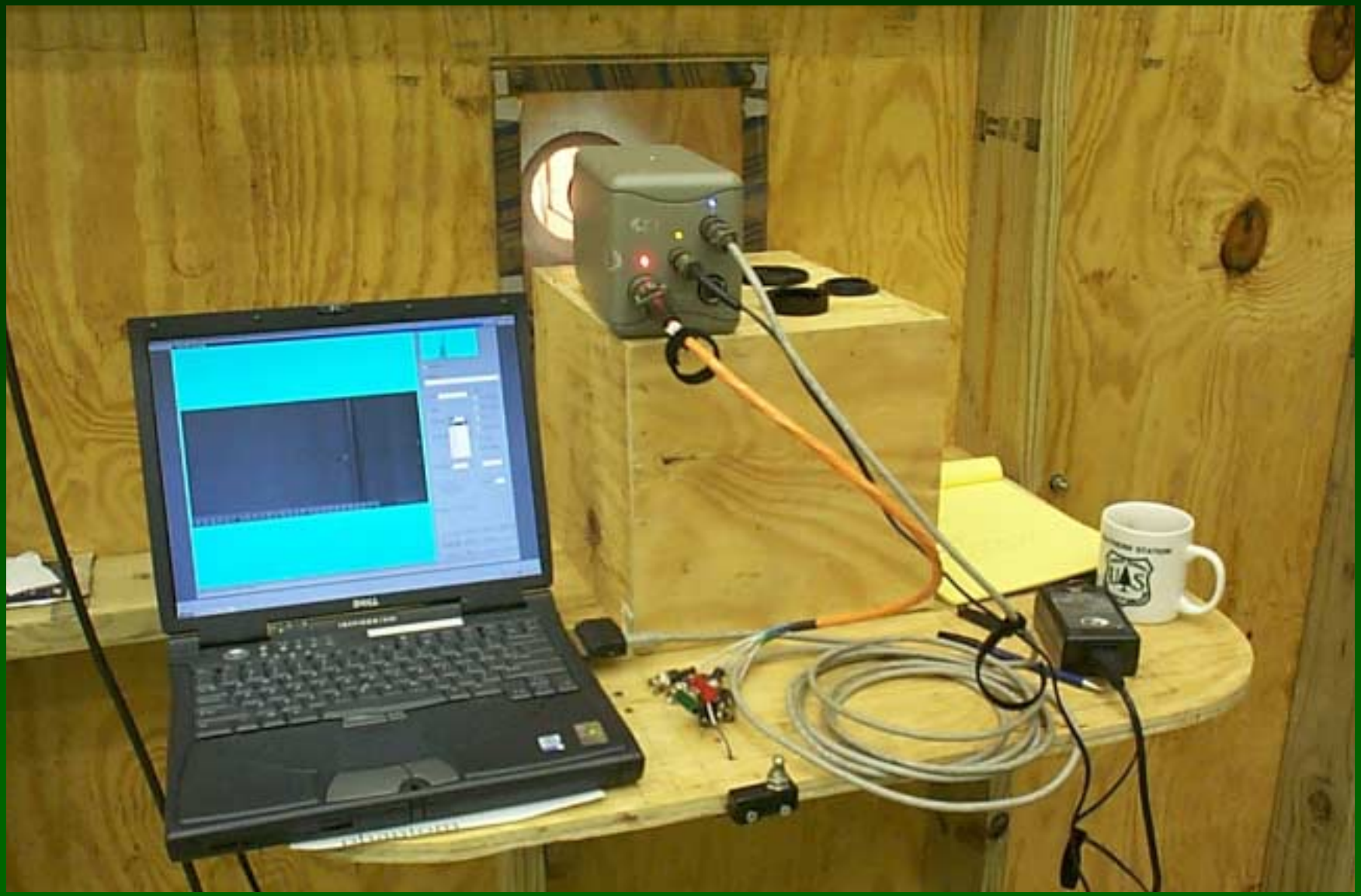
- Two methods are being used to analyze rollover behavior of excavator-based forest machines:
  - Rigid Body mechanics
  - Multiphysics simulation
- Relationships between machine mass and energy exposure levels during rollover for typical hydraulic excavators are similar to those of crawler tractors
- Forestry modifications can affect rollover behavior and should be considered in safety standards
  - Cab risers
  - Boom configurations

} Affect stability, energy, forces

Thrown Object Hazards

Testing Facility

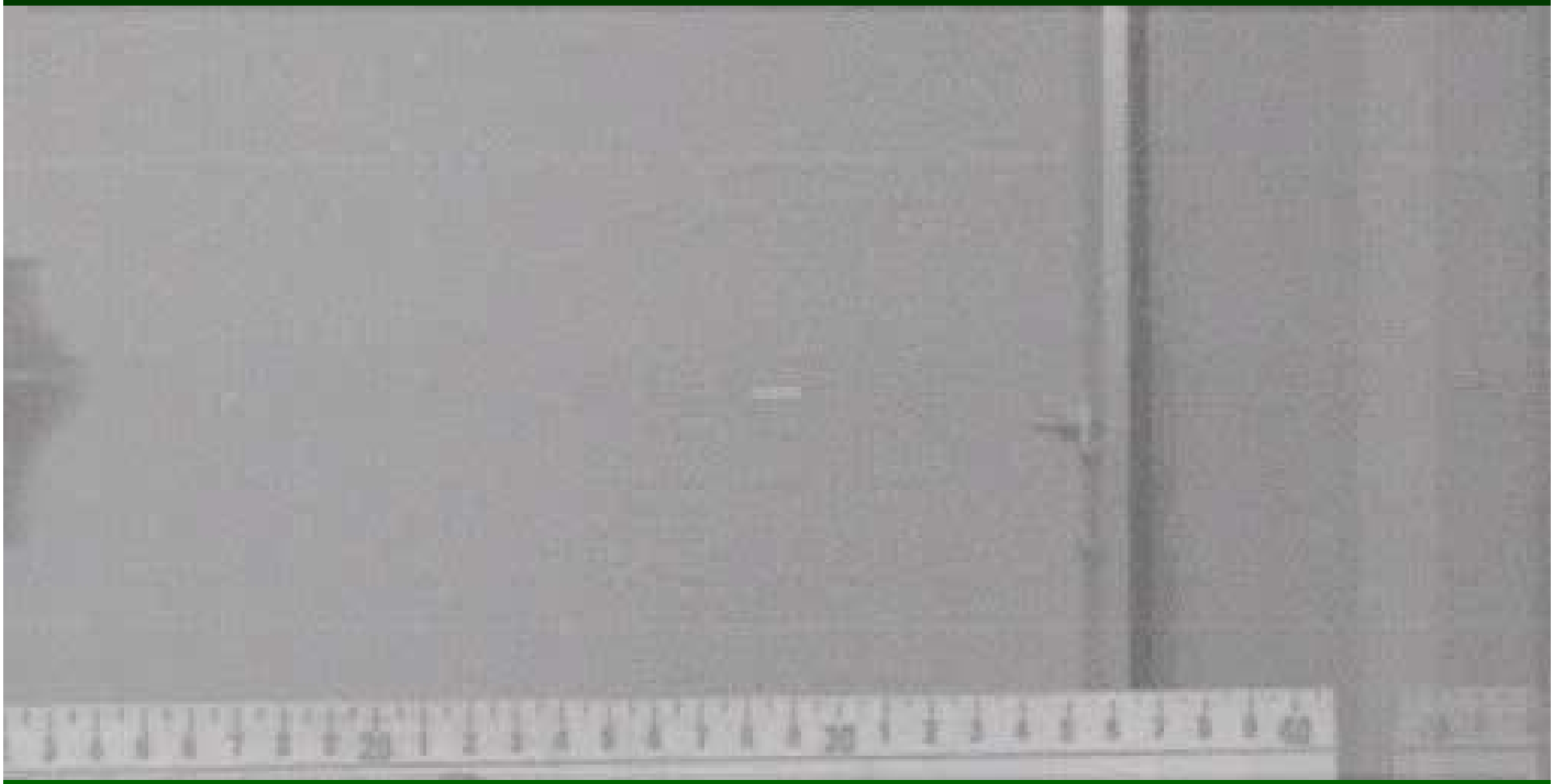




Test Program

- Steel (3 mm, 4.7 mm, 6.3 mm)
- Polycarbonate (12 mm mono, 19 mm)
- Velocity (60 – 150 m/s)
- Sawtooth (350 g, 600 g)
- Chain link

High Speed Video Test Footage
95 m/s, 600 g object



Polycarbonate Results

		Pass	Fail
13 mm mono	Velocity (m/s)	83	87
	Energy in (kJ)	6.8	7.5
	Energy absorbed (kJ)	6.4	6.3
19 mm 3-ply	Velocity (m/s)	105	113
	Energy in (kJ)	11.0	13.0
	Energy absorbed (kJ)	10.5	12.5

Impact Result: 19 mm @ 113 m/s

Birefringence pattern

Summary of Thrown Object Tests

- At current sawhead design velocities, 6 mm steel skins are necessary to withstand impact
- Laminated 19 mm Lexan is insufficient to withstand impact of sawhead teeth
- There may be crossover between ballistic rating and forestry applications
- Chain shot event needs further study

Closing Remarks

- As forest machines continue to evolve, new issues develop for safety standards
- Research needs to keep pace with new machine developments
- Current results on excavator ROPS will be used in next revision of ISO 8082

- Current results on thrown objects will be incorporated in future standards